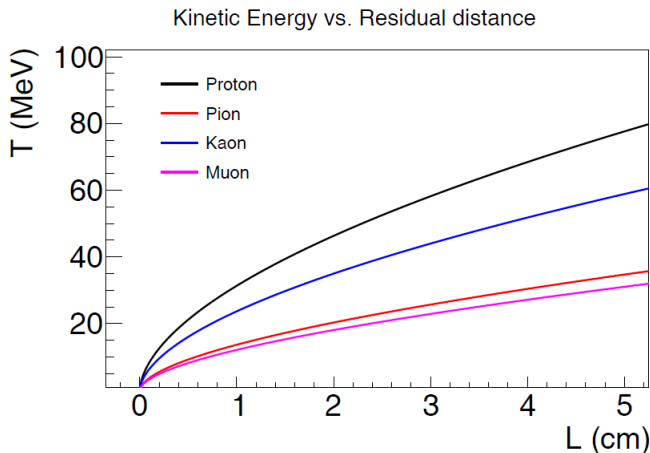# Continued Study of Parallel Events

Brendon Bullard
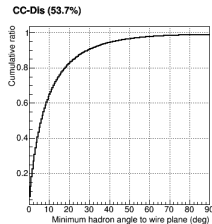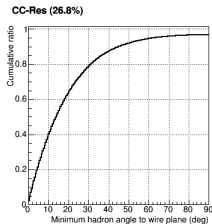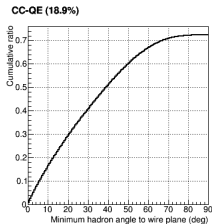
July 13, 2016

Adding Hadronic Cuts

Kinetic Energy vs. Residual distance
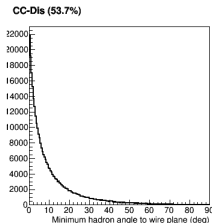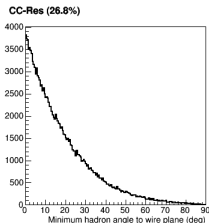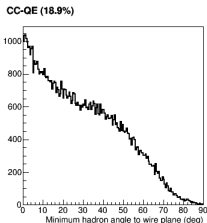
- ▶ Hadrons that don't travel far shouldn't affect reconstruction
- ▶ Cut hadrons that stop before traveling 1.5 cm
- ▶ Energy threshold of 17.5, 30, and 39 MeV for pion, kaon, and proton, respectively

Adding Hadronic Cuts

- 10^6 simulated events, 602,092 CC events (562,003 after energy cut)
- Required lepton energy < 6 GeV; exclude neutrons and neutral pions
- Throw out particles having energy less than the threshold
- Record minimum angle of a hadron to the wire plane

Adding Hadronic Cuts

If we require both the lepton and at least one hadron passing the energy threshold to be within a small angle to the wire plane:

|	CC QE	CC Res	CC DIS
Hadron $< 5°$	9.0%	21.5%	43.5%
Both $< 5°$	2.7%	6.0%	7.7%
Hadron $< 7.5°$	12.4%	30.5%	55.0%
Both $< 7.5°$	5.6%	12.2%	14.8%
Hadron $< 10°$	16.0%	38.6%	63.5%
Both $< 10°$	9.0%	19.6%	23.1%

► Represents the percentage of events where the lepton and at least one energetic hadron are overlapping and degenerate → more difficult to reconstruct

► Adding energy cut reduces problematic cases by factor of ∼2

π^0 Decay Backgrounds

- Neutral pions can be produced in ν_e interactions
- The main decay mode is $\pi^0 \to 2\gamma$, which constitutes a large background for the signal $\nu_e n \to ep$
- It is difficult to distinguish this background from a true signal if one of the photons converts to an electron within 3 cm
- MC used does not decay final state pions $\to$ use TGenPhaseSpace to simulate decay
- Select smallest photon angle relative to the wire plane
- Simulate radiation length of photon using TRandom3::Exp()
- For now, assume converted electron is parallel to photon
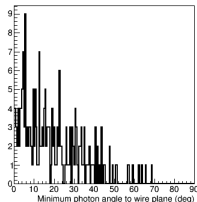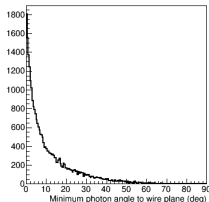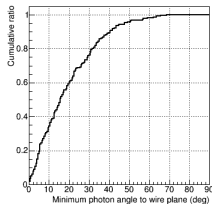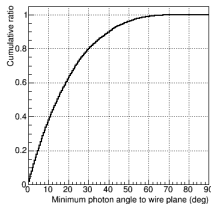
π^0 Decay Backgrounds - CC
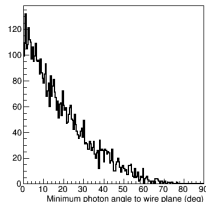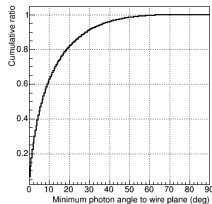
- Percentages are of events in each channel to all CC with $E_e < 6$ GeV
- 10^6 simulated events, 32,789 events having a final state π^0
- Required lepton energy < 6 GeV
- Record minimum angle of a photon to wire plane, consider all photons produced by all π^0 per event

π^0 Decay Backgrounds - CC

If we require both the lepton and at least one photon to be within a small angle to the wire plane:

	CC QE	CC Res	CC DIS
Photon $< 5°$	18.2%	19.8%	41.9%
Both $< 5°$	5.7%	5.5%	7.4%
Photon $< 7.5°$	27.0%	28.7%	53.1%
Both $< 7.5°$	12.2%	11.5%	14.3%
Photon $< 10°$	33.5%	36.7%	61.4%
Both $< 10°$	18.9%	18.6%	22.3%

▶ Represents the percentage of events where the lepton and at least one short-lived photon are overlapping and degenerate within certain angle $\rightarrow$ more difficult to reconstruct

▶ DIS is most problematic due to greater number of hadrons produced
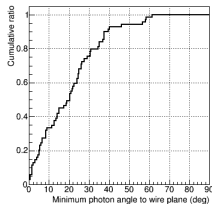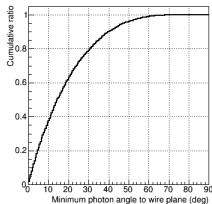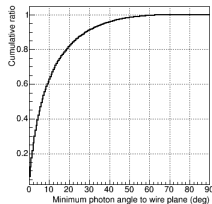
- Percentages are of events in each channel to all NC with $E_e < 6$ GeV
- 10^6 simulated events, 202,698 NC, 12,801 events having a final state π^0
- Required lepton energy < 6 GeV
- Record minimum angle of a photon to wire plane, consider all photons produced by all π^0 per event
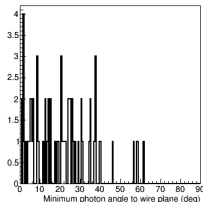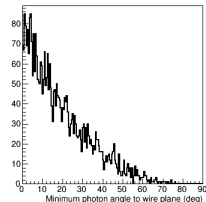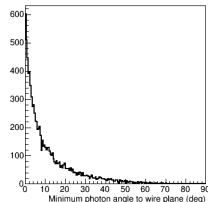
π^0 Decay Backgrounds - NC

If we require at least one photon to be within a small angle to the wire plane:

	NC QE	NC Res	NC DIS
Photon $< 5°$	17.4%	20.3%	42.1%
Photon $< 7.5°$	27.5%	29.0%	53.6%
Photon $< 10°$	33.3%	36.4%	61.5%

- ► Represents the percentage of events where at least one short-lived photon is degenerate within specified angle
- ► Again, DIS is most problematic due to more hadrons produced

- π^0 can decay to photons inside an Ar nucleus. Should also consider photons when computing the minimum angle of hadrons
- Find out how many π^0 decay to photons inside the Ar nucleus
- Combine results from hadron$+\gamma$ with $\pi^0 \to 2\gamma$ to understand all CC events that affect reconstruction

MC Files

`fastmcNtp_20140711_lbne_g4lbnev3r2p4_nuflux_numuflux_nue_`
`LAr_1_g280_Ar40_5000_Default.root`

- Fully oscillated ν_μ beam; used for hadron and CC π^0 decay studies

`fastmcNtp_20140711_lbne_g4lbnev3r2p4_nuflux_numuflux_numu_`
`LAr_1_g280_Ar40_5000_Default.root`

- Unoscillated ν_μ beam; used for NC π^0 decay studies